THE EFFECT OF HIGH ENVIRONMENTAL TEMPERATURE ON THE WATER DISTRIBUTION IN THE BODY

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The literature on water metabolism during exposure of the body to a high environmental temperature is comparatively extensive [1, 2, 3, 6, 7, 12]. The information given in the literature is mainly concerned with the exchange of water between the body and the environment through the lungs, skin, kidneys and gastrointestinal tract. So far, however, little attention has been paid to the interchange of water within the body between the various fluid media (blood plasma, extracellular and intracellular fluids). Nevertheless, changes in the quantity of extra- and intracellular water may be the cause of disturbances of metabolism and of the functions of various organs and systems of the body during exposure to a high environmental temperature [4, 5, 11]. We have previously shown [8] that during exposure of the body to a high environmental temperature (40-42°), in addition to a general small loss of water (about 1-2%), there also occurs a considerable redistribution of water in the organs and tissues, in the form of an increase in the quantity of extracellular and a decrease in the intracellular water. R.V. Chagovets [9] put forward the suggestion that under these conditions a peculiar "desiccation" of the cells takes place, with no significant loss in the total water content of the tissues associated with the change in the metabolism during overheating and, in particular, with profound changes in the tissue proteins. The essence of this phenomenon evidently also includes changes in the physicochemical properties of the intracellular colloids, most probably in the appearance of states which are accompanied by a reduction in the power of the colloids of the protoplasm to undergo swelling and to combine with certain ions.

The aim of the present investigation was to define the degree and the nature of the loss of water by the body during exposure to a high environmental temperature and to study the character of the changes in water distribution between the internal fluid media (blood plasma, extracellular fluid, intracellular fluid) with a negative water balance.

EXPERIMENTAL METHOD

The water metabolism of rabbits was studied by the usual methods, and the distribution of water in the body as a whole was examined in the same animal by the aid of radioactive isotopes.

The content of total water, extracellular fluid, intracellular water and water of the blood was determined indirectly from the following information: 1) the total loss of water was estimated from the fall in the body weight of the animal during the experiment, allowing for the excretion of urine and feces; 2) the origin of the water expended was estimated by the change in volume of the extracellular fluid and of the fluid part of the blood of the animal when exposed to a high environmental temperature by comparison with these values under ordinary temperature conditions; 3) the change in the content of intracellular water was estimated from the results of 1 and 2.

The total loss of water was determined by weighing the animal. The difference between the total loss of water and the volume of urine excreted gave the extrarenal water loss.

The volume of the extracellular fluid was calculated by subtracting the volume of the plasma from the volume of the "radiosulfate" space, including the extracellular water and the water of the plasma. The volume of the "radiosulfate" space was determined with the aid of sodium sulfate, labeled with S^{35} [8], and the blood volume was measured by using red cells labeled with radioactive phosphorus [11].

These investigations were carried out by means of a method which we ourselves devised for simultaneous determination of the "radiosulfate" space and the blood volume in the same animal, using one single injection of the two radioactive isotopes S^{35} and P^{32}.

The volume of the fluid part of the blood (plasma volume) was calculated by subtracting the volume of the red cells from the total volume of the blood. The red cell volume and hemoglobin content were estimated from the specific gravity of the blood and plasma by the falling drop method in a solution of copper sulfate [12]. The change in the red cell dimensions during exposure to high temperatures was determined by the method sug - gested by N. V. Danilov [1].

As a control we used the analogous hematological indices as established in the rabbits at the beginning of the experiment, before exposure to high temperatures, and at ordinary room temperature (18-20°C). In these conditions the volume of the "radiosulfate" space and the blood volume of the rabbits were determined.

In order to ascertain the effect of the temperature factor, experiments were performed in which heating took place in a warm room-incubator at a temperature of 42-45° for a period of 3 hours, without taking food.

The investigations were carried out on 6 adult rabbits, weighing 2-3 kg. Repeated experiments on the same rabbits were performed after not less than 20 days. Altogether, 19 experiments were performed. Control experiments wer carried out on 10 rabbits at ordinary room temperature (18-20°C).

EXPERIMENTAL RESULTS

The investigations showed that by exposure of the animals to a high temperature (42-45°C) for 3 hours without food, their rectal temperature rose by 1.7-3.6°C (on the average by 2.5°).

TABLE 1

Loss of Water from a Rabbit during Exposure to a High Temperature (42-45°C) for 3 Hours without Water

No. of experiments	Body weight after heating	Loss of water					
		Total		In the urine		Extrarenal	
		in ml	as % of body weight	in ml	as a % of the total loss	in ml	as a % of the total loss
19	2718.2	60.8	2.16	7.0	10.12	57.85	95.74
	± 76.5	±3.9	±0.12	±0.8	± 1.3	± 3.6	± 1.3

The experimental results given in Table 1 demonstrate that the water balance was disturbed during exposure to a high environmental temperature, and that, in fact there was a negative water balance amounting to 2.16% of the body weight. Under these circumstances, changes appeared in the character of the water loss and of the distribution of water in the body. In the majority of the rabbits, diuresis accounted for on the average, about 10.12% of the total loss of water, and in some experiments diuresis was completely absent. The extrarenal water loss comprised, on the average, about 95.75% of the total loss of water.

It follows from the results given in Table 2 that during exposure to a high environmental temperature (42-45°C) the volume of the "radiosulfate" space of the rabbit rose mainly on account of an increase in the volume of extracellular water and of a slight increase in the plasma volume.

Furthermore, on the basis of results indicating an increase in the dimensions of the red cells (Table 3), some retention of water in the red cells might be assumed.

TABLE 2

Distribution of Water in the Body of Rabbits Kept at Ordinary Temperatures (18-20°C) and of Rabbits Exposed to High Temperature (43-45°) without Water

Experimental conditions	Number of experiments	Volume of "radiosulfate" space (in ml)	Blood volume (in ml)	Red cell volume (in ml)	Plasma volume (in ml)	Volume of extracellular water (in ml)
Control (18-20°C)	29	803.5±38.0	124±3.2	49.2	74.8	728.7
Temperature of 43-45°C without water	19	860.5±34.2	120.1±5.0	39.5±1.8	80.4±4.5	780.1

TABLE 3

Changes in the Red Cell Count, the Hemoglobin Content and the Dimensions of the Red Cells of Rabbits Exposed to High Temperatures by Comparison with Controls (18-20°C)

Number of experiments	Decrease in red cell count (in %)	Decrease in hemoglobin (in %)	Decrease in dimensions of red cells (in %)
19	10.6±1.3	1.02±0.33	6.91±1.2

Bearing in mind that,during the exposure to high temperatures (for a period of 3 hours),no water was taken into the body, it could be accepted that the source of the loss of water indicated and of the increased water content of the extracellular spaces of the body is the internal reserves, i.e.,the intracellular water.

Thus,during exposure of rabbits to a high environmental temperature (43-45°C) with inadequate water to drink or none at all, a negative water balance was found, amounting to 2.0-2.5% of the body weight. Diuresis was reduced, and,in several cases,was absent altogether. Water was expended mainly by extrarenal loss. In these conditions,the water content of the extracellular spaces was increased and at the same time there was a decrease in the volume of water within the cells. The blood volume and the volume and number or red cells were decreased, whereas the dimensions of the red cells were increased.

SUMMARY

Water distribution among various liquid media was studied in rabbits under high external temperatures (+43°, +45°C) by the concurrent determination of the volume of blood and cellular fluid,with the aid of radioactive isotopes. The total water loss and the changes of certain hematological indices were also investigated. The loss of water during a 3-hour exposition of the rabbit to heating with no water to drink amounted to from 2 to 2.5% of the body weight. Diuresis decreases or is completely absent. All the water losses occur at the expence of the extrarenal losses. The volume of the extracellular water increases, while that of the blood plasma slightly rises. Intracellular water serves as a source of the water loss and its increase in the extracellular spaces.

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